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(54) Title: **RAPID ACTING DRUG DELIVERY COMPOSITIONS**

(57) **Abstract:** Drug formulations for systemic drug delivery with improved stability and rapid onset of action are described herein. The formulations may be administered via buccal administration, sublingual administration, pulmonary delivery, nasal administration, subcutaneous administration, rectal administration, vaginal administration, or ocular administration. In the preferred embodiments, the formulations are administered sublingually or via subcutaneous injection. The formulations contain an active agent and one or more excipients, selected to increase the rate of dissolution. In the preferred embodiment, the drug is insulin, and the excipients include a metal chelator such as EDTA and an acid such as citric acid.



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RAPID ACTING DRUG DELIVERY COMPOSITIONS
CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S.S.N. 60/552,637, entitled
“*Sublingual Drug Delivery Compositions*” by Roderike Pohl and Solomon S.
5 Steiner filed March 12, 2004, and U.S.S.N. 60/609,194, entitled “*Sublingual*
Drug Delivery Compositions” by Roderike Pohl and Solomon S. Steiner
filed September 9, 2004.

FIELD THE INVENTION

The invention is in the general field of rapid acting drug delivery
10 formulations.

BACKGROUND OF THE INVENTION

An effective, non-invasive oral delivery system for peptides, in
general, and insulin, in particular, has not been developed to date, due to
several limiting factors. First, tablets or liquids containing peptides, such as
15 insulin, are readily digested in the harsh stomach environment, and thus
require extensive protection to survive and be absorbed. Food effects and
individual gastrointestinal (GI) transit times confound a dependable temporal
or quantitative delivery.

The lack of effective oral delivery means is further complicated in
20 some cases. For example, insulin is most stable in its hexameric form (six
insulin monomers assembled around zinc ions). Therefore, it is preferable to
store it in this form for greater shelf-life stability. However, this form is too
large for rapid absorption through tissue membranes.

U.S. Patent No. 6,676,931 to Dugger, III discloses liquid sprays that
25 deliver an active agent to the mouth for absorption through the oral mucosa.
U.S. Patent No. 6,676,931 notes that the active agent may be insulin lispro,
which is a rapidly-acting human insulin analog that contains hexameric
insulin. However, such liquid sprays are not very useful for delivering
hexameric insulin due to its poor absorption. Additionally, many active
30 agents are not stable in the liquid form and cannot be stored in liquid form.

Buccal administration using sprays of insulin has been attempted
with limited bioavailability since hexameric insulin is not readily absorbed

and liquids are eventually swallowed. The administered dose is not rapidly absorbed, and has an absorption profile similar to subcutaneous injection. Also, due to its poor bioavailability, a large dose is required for a useful glucose lowering effect. Thus, it is not a cost effective or therapeutic alternative.

Pulmonary formulations are being developed and may provide a good alternative to injection. However, these formulations require the use of an inhaler and may lack good patient compliance if the delivery technique is complicated.

Therefore it is an object of the invention to provide oral drug delivery compositions with improved stability and rapid onset of action.

It is a further object of the invention to provide methods for storing drugs and rapidly delivering drugs.

SUMMARY OF THE INVENTION

Drug formulations for systemic drug delivery with improved stability and rapid onset of action are described herein. The formulations may be administered via buccal administration, sublingual administration, pulmonary delivery, nasal administration, subcutaneous administration, rectal administration, vaginal administration, or ocular administration. In the preferred embodiments, the formulations are administered sublingually or via subcutaneous injection. The formulations contain an active agent and one or more excipients selected to increase the rate of dissolution. In the preferred embodiment, the drug is insulin, and the excipients include a metal chelator such as EDTA and an acid such as citric acid. Following administration, these formulations are rapidly absorbed by the oral mucosa when administered sublingually and are rapidly absorbed into the blood stream when administered by subcutaneous injection. In one embodiment, the composition is in the form of a dry powder. In another embodiment, the composition is in the form of a film, wafer, lozenge, capsule, or tablet. In a third embodiment, a dry powdered insulin is mixed with a diluent containing a pharmaceutically acceptable carrier, such as water or saline, a metal

chelator such as EDTA and an acid such as citric acid. Devices for storing and mixing these formulations are also described.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a is a schematic for the delivery of a dry powder insulin composition: Figure 1b is schematic for the delivery of a lozenge composition.

Figure 2 is a perspective view of a vial containing powdered insulin in the cap, separated by a seal which can be broken by rotation of the cap, to allow the insulin to mix with the citric acid-EDTA solution in the vial.

Figure 3 is a bar graph showing the percentage of total insulin that was transferred through a 30,000 molecular weight cut-off membrane (i.e. a filter) in the presence of varying quantities of EDTA.

Figure 4 is a graph of the effect of EDTA alone or in combination with citric acid, hydrochloric acid, acetic acid, and ascorbic acid, on the percent of low molecular weight (i.e., monomeric) insulin.

Figures 5a-5d are graphs of the percent of low molecular weight insulin in the presence of HCl (Figure 5a), ascorbic acid (Figure 5b), citric acid (Figure 5c), and acetic acid (Figure 5d), alone or in combination with EDTA, at either pH 3.0 or pH 7.0.

Figure 6 is a graph of decrease in blood glucose following subcutaneous administration of insulin in combination with citric acid and EDTA.

Figure 7 is a graph of the mean insulin accumulation (μ U) over time (minutes) in the lower chamber of a transwell membrane plate seeded with epithelial cells, comparing the effect of an insulin formulation containing EDTA (\blacklozenge) with one without EDTA (\blacksquare), with a control, no cells (\blacktriangle).

DETAILED DESCRIPTION OF THE INVENTION

I. Compositions

Formulations including an active agent, such as insulin, and one or more excipients, such as a chelator and/or solubilizing agent, that dissolve rapidly in aqueous media are described herein. In the preferred embodiment, the formulations are suitable for subcutaneous or sublingual

administration. These formulations are rapidly absorbed through mucosal surfaces (parenteral, pulmonary, etc.) and through the fatty tissue when administered subcutaneously. This is achieved through the addition of excipients, especially solubilizers such as acids and metal chelators.

5 **Definitions**

As generally used herein, a drug is considered "highly soluble" when the highest dose strength is soluble in 250 ml or less of aqueous media over the pH range of 1-7.5. The volume estimate of 250 ml is derived from typical bioequivalence (BE) study protocols that prescribe administration of a drug product to fasting human volunteers with a glass (about 8 ounces) of water. A drug is considered highly soluble when 90% or more of an administered dose, based on a mass determination or in comparison to an intravenous reference dose, is dissolved. Solubility can be measured by the shake-flask or titration method or analysis by a validated stability-indicating assay.

As generally used herein, an immediate release drug formulation is considered "rapidly dissolving" when no less than 85% of the labeled amount of the drug substance dissolves within 30 minutes, using U.S. Pharmacopeia (USP) Apparatus I at 100 rpm (or Apparatus II at 50 rpm) in a volume of 900 ml or less in each of the following media: (1) 0.1 N HCl or Simulated Gastric Fluid USP without enzymes; (2) a pH 4.5 buffer; and (3) a pH 6.8 buffer or Simulated Intestinal Fluid USP without enzymes.

20 **Pharmaceutically Active Agents**

Although described with reference to insulin, the formulations may be used with other agents, including peptides, proteins, nucleotide molecules (RNA sequences, DNA sequences), sugars, polysaccharides, and small organic molecules. Preferably, the active agent is at least slightly soluble in aqueous medium (i.e. 10,000 parts of aqueous solvent per solute), and more preferably is highly soluble in aqueous medium. Preferably the active agent is highly potent, so that only a small amount (e.g. in the microgram range) is needed to provide a therapeutic effect. Suitable peptides include but are not limited to insulin and derivatives of insulin, such as lispro; C-peptide;

glucagon-like peptide 1 (GLP 1) and all active fragments thereof; human amylin and synthetic forms of amylin, such as pramlintide; parathyroid hormone (PTH) and active fragments thereof (e.g. PTH₁₋₃₄); calcitonin; human growth hormone (HGH); erythropoietin (EPO); macrophage-colony stimulating factor (M-CSF); granulocyte-macrophage-colony stimulating factor (GM-CSF); and interleukins. In the preferred embodiment the active agent is insulin. Suitable small molecules include nitroglycerin, sumatriptan, narcotics (e.g. fentanyl, codeine, propoxyphene, hydrocodone, and oxycodone), benzodiazepines (e.g. Alprazolam, Clobazam, Clonazepam, Diazepam, Flunitrazepam, Lorazepam, Nitrazepam, Oxazepam, Temazepam, and Triazolam), phenothiazines (Chlorpromazine, Fluphenazine, Mesoridazine, Methotrimeprazine, Pericyazine, Perphenazine, Prochlorperazine, Thioproperazine, Thioridazine, and Trifluoperazine), and selective serotonin reuptake inhibitors (SSRIs) (e.g. sertraline, fluvoxamine, fluoxetine, citalopram, and paroxetine).

In the preferred embodiment, the active agent is insulin or an analog or derivative thereof. The insulin can be recombinant or purified. In the preferred embodiment, the insulin is human insulin. Recombinant human insulin is available from a number of sources.

The dosages of the active agents depend on their bioavailability and the disease or disorder to be treated. Insulin is generally included in a dosage range of 12 to 2000 IU per human dose. Thus if the insulin has a bioavailability 5-25%, the actual systemic dose delivered to an individual ranges from 3 to 100 IU. For insulin with only 2.5 % bioavailability, an oral dose of 4,000 IU will deliver a 100 IU systemically available dose. For insulin with a much greater bioavailability, such as a 50% bioavailability, the delivery of a 3 IU systemically available dose requires an oral dose of 6 IU.

Formulations

The compositions contain one or more excipients. In the preferred embodiment, at least one of the excipients is selected to mask any charges on the active agent. This facilitates the transmembrane transport for the active agent and thereby increases both the onset of action and bioavailability for

the active agent. The excipients are also selected to form compositions that dissolve rapidly in aqueous medium. Optional pharmaceutically acceptable excipients present in the drug-containing tablets, beads, granules or particles include, but are not limited to, diluents, binders, lubricants, disintegrants, colorants, stabilizers, and surfactants.

Solubilizing agents

In the preferred embodiment, one or more solubilizing agents are included with the active agent to promote rapid dissolution in aqueous media. Suitable solubilizing agents include wetting agents such as polysorbates and poloxamers, non-ionic and ionic surfactants, food acids and bases (e.g. sodium bicarbonate), and alcohols, and buffer salts for pH control. Suitable acids include acetic acid, ascorbic acid, citric acid, and hydrochloric acid. For example, if the active agent is insulin, a preferred solubilizing agent is citric acid.

Chelators

In the preferred embodiment, a metal chelator is mixed with the active agent or in a coating surrounding the active agent. The chelator may be ionic or non-ionic. Suitable chelators include ethylenediaminetetraacetic acid (EDTA), citric acid, dimercaprol (BAL), penicillamine, alginic acid, chlorella, cilantro, alpha lipoic acid, dimercaptosuccinic acid (DMSA), dimercaptopropane sulfonate (DMPS), and oxalic acid. In the preferred embodiment, the chelator is EDTA. The chelator hydrogen bonds with the active agent, thereby masking the charge of the active agent and facilitating transmembrane transport of the active agent. For example, when the active agent is insulin, in addition to charge masking, it is believed that the chelator pulls the zinc away from the insulin, thereby favoring the monomeric form of the insulin over the hexameric form and facilitating absorption of the insulin by the tissues surrounding the site of administration (e.g. mucosa, or fatty tissue). Optionally, the chelator and solubilizing agent are the same compound.

Ions may be part of the active agent, added to the stabilizing agent, mixed with the chelator, and/or included in the coating. Representative ions

include zinc, calcium, iron, manganese, magnesium, aluminum, cobalt, copper, or any di-valent metal or transitional metal ion. Zn^{+2} has a stronger binding preference for EDTA than Ca^{+2} .

Diluents and Fillers

5 Diluents, also referred to herein as fillers, are typically necessary to increase the bulk of a solid dosage form so that a practical size is provided for compression of tablets or formation of beads and granules. Suitable fillers include, but are not limited to, dicalcium phosphate dihydrate, calcium sulfate, lactose, sucrose, mannitol, sorbitol, cellulose, microcrystalline
10 cellulose, powdered cellulose, kaolin, sodium chloride, dry starch, hydrolyzed starches, pregelatinized starch, silicone dioxide, titanium oxide, magnesium aluminum silicate, calcium carbonate, compressible sugar, sugar spheres, powdered (confectioner's) sugar, dextrates, dextrin, dextrose, dibasic calcium phosphate dehydrate, glyceryl palmitostearate, magnesium
15 carbonate, magnesium oxide, maltodextrin, polymethacrylates, potassium chloride, talc, and tribasic calcium phosphate.

Binders

Binders are used to impart cohesive qualities to a solid dosage formulation, and thus ensure that a tablet, bead or granule remains intact
20 after the formation of the dosage forms. Suitable binder materials include, but are not limited to, starch, pregelatinized starch, gelatin, sugars (including sucrose, glucose, dextrose, lactose and sorbitol), dextrin, maltodextrin, zein, polyethylene glycol, waxes, natural and synthetic gums such as acacia, guar gum, tragacanth, alginate, sodium alginate, celluloses, including
25 hydroxypropylmethylcellulose, carboxymethylcellulose sodium, hydroxypropylcellulose, hydroxyethylcellulose, ethylcellulose, methyl cellulose, and veegum, hydrogenated vegetable oil, Type I, magnesium aluminum silicate, and synthetic polymers such as acrylic acid and methacrylic acid copolymers, carbomer, methacrylic acid copolymers,
30 methyl methacrylate copolymers, aminoalkyl methacrylate copolymers, polyacrylic acid/polymethacrylic acid, and polyvinylpyrrolidone.

Lubricants

Lubricants are used to facilitate tablet manufacture. Examples of suitable lubricants include, but are not limited to, magnesium stearate, calcium stearate, stearic acid, glyceryl behenate, glyceryl monostearate, glyceryl palmitostearate, hydrogenated castor oil, hydrogenated vegetable oil, type I, sodium benzoate, sodium lauryl sulfate, sodium stearyl fumarate, polyethylene glycol, talc, zinc stearate, and mineral oil and light mineral oil.

Disintegrants

Disintegrants are used to facilitate dosage form disintegration or "breakup" after administration, and generally include, but are not limited to, starch, sodium starch glycolate, sodium carboxymethyl starch, methylcellulose, calcium carboxymethylcellulose, sodium carboxymethylcellulose, hydroxypropyl cellulose, microcrystalline cellulose, colloidal silicon dioxide, croscarmellose sodium, pregelatinized starch, clays, cellulose, powdered cellulose, pregelatinized starch, sodium starch glycolate, sodium alginate, alginic acid, guar gum, magnesium aluminum silicate, polacrillin potassium, and cross linked polymers, such as cross-linked PVP, crospovidone (POLYPLASDONE® XL from GAF Chemical Corp).

Stabilizers

Stabilizers are used to inhibit or retard drug decomposition reactions which include, by way of example, oxidative reactions. A number of stabilizers may be used. Suitable stabilizers include polysaccharides, such as cellulose and cellulose derivatives, and simple alcohols, such as glycerol; bacteriostatic agents such as phenol, m-cresol and methylparaben; isotonic agents, such as sodium chloride, glycerol, and glucose; lecithins, such as example natural lecithins (e.g. egg yolk lecithin or soya bean lecithin) and synthetic or semisynthetic lecithins (e.g. dimyristoylphosphatidylcholine, dipalmitoylphosphatidylcholine or distearoyl-phosphatidylcholine; phosphatidic acids; phosphatidylethanolamines; phosphatidylserines such as distearoyl-phosphatidylserine, dipalmitoylphosphatidylserine and diarachidoylphosphahtidylserine; phosphatidylglycerols; phosphatidylinositols; cardiolipins; sphingomyelins; and synthetic

detergents, such as diosctanoylphosphatidyl choline and polyethylene-polypropylene glycol). Other suitable stabilizers include acacia, albumin, alginic acid, bentonite, carboxymethylcellulose calcium, carboxymethylcellulose sodium, cyclodextrins, glyceryl monostearate, hydroxypropyl cellulose, hydroxypropyl methylcellulose, magnesium aluminum silicate, propylene glycol, propylene glycol alginate, sodium alginate, white wax, xanthan gum, and yellow wax. In the preferred embodiment, the agent is insulin and the stabilizer may be a combination of one or more polysaccharides and glycerol, bacteriostatic agents, isotonic agents, lecithins, or synthetic detergents.

Surfactants

Surfactants may be anionic, cationic, amphoteric or nonionic surface active agents. Suitable anionic surfactants include, but are not limited to, those containing carboxylate, sulfonate and sulfate ions. Examples of anionic surfactants include sodium, potassium, ammonium of long chain alkyl sulfonates and alkyl aryl sulfonates such as sodium dodecylbenzene sulfonate; dialkyl sodium sulfosuccinates, such as sodium dodecylbenzene sulfonate; dialkyl sodium sulfosuccinates, such as sodium bis-(2-ethylthioxy)-sulfosuccinate; and alkyl sulfates such as sodium lauryl sulfate. Cationic surfactants include, but are not limited to, quaternary ammonium compounds such as benzalkonium chloride, benzethonium chloride, cetrimonium bromide, stearyl dimethylbenzyl ammonium chloride, polyoxyethylene and coconut amine. Examples of nonionic surfactants include ethylene glycol monostearate, propylene glycol myristate, glyceryl monostearate, glyceryl stearate, polyglyceryl-4-oleate, sorbitan acylate, sucrose acylate, PEG-150 laurate, PEG-400 monolaurate, polyoxyethylene monolaurate, polysorbates, polyoxyethylene octylphenylether, PEG-1000 cetyl ether, polyoxyethylene tridecyl ether, polypropylene glycol butyl ether, Poloxamer[®] 401, stearyl monoisopropanolamide, and polyoxyethylene hydrogenated tallow amide. Examples of amphoteric surfactants include sodium N-dodecyl- β -alanine, sodium N-lauryl- β -iminodipropionate, myristoamphoacetate, lauryl betaine and lauryl sulfobetaine.

If desired, the tablets, wafers, films, lozenges, beads, granules, or particles may also contain minor amount of nontoxic auxiliary substances such as dyes, sweeteners, coloring and flavoring agents, pH buffering agents, or preservatives.

5 **Polymers**

Blending or copolymerization sufficient to provide a certain amount of hydrophilic character can be useful to improve wettability of the materials. For example, about 5% to about 20% of monomers may be hydrophilic monomers. Hydrophilic polymers such as hydroxypropylcellulose (HPC),
10 hydroxypropylmethylcellulose (HPMC), carboxymethylcellulose (CMC) are commonly used for this purpose. Also suitable are hydrophobic polymers such as polyesters and polyimides. It is known to those skilled in the art that these polymers may be blended with polyanhydrides to achieve compositions with different drug release profiles and mechanical strengths. Preferably, the
15 polymers are bioerodable, with preferred molecular weights ranging from 1000 to 15,000 Da, and most preferably 2000 to 5000 Da.

Formulations

The active compounds (or pharmaceutically acceptable salts thereof) may be administered in the form of a pharmaceutical composition wherein
20 the active compound(s) is in admixture or mixture with one or more pharmaceutically acceptable carriers, excipients or diluents. Suitable dosage forms include powders, films, wafers, lozenges, capsules, and tablets. The compositions may be administered in a variety of manners, including buccal administration, nasal administration, pulmonary administration, sublingual
25 administration, and subcutaneous administration. Following administration, the dosage form dissolves quickly releasing the drug or forming small particles containing drug, optionally containing one or more excipients.

The formulation may dissolve in a time period ranging from 1 second to 3 minutes, 3 to 5 minutes, 5 to 8 minutes, or 8 to 12 minutes. The
30 preferred dissolution time is less than 30 seconds. Preferably the drug is absorbed and transported to the plasma quickly, resulting in a rapid onset of

action (preferably beginning within about 5 minutes following administration and peaking at about 15-30 minutes following administration).

In one preferred embodiment, the formulation is a sublingual solid formulation that contains an active agent, and at least one solubilizing agent, along with other standard excipients, such as poly(vinyl alcohol), glycerin, carboxymethyl cellulose (CMC), and optionally poly(ethylene glycol) and water. In the preferred embodiment the active agent is insulin and the solubilizing agents are ethylenediaminetetraacetic acid (EDTA), and citric acid. The sublingual composition may be in the form of a dry powder, monolayer, bilayer, or trilayer film, a lyophilized wafer, lozenge, capsule, or a tablet.

In a second preferred embodiment, the formulation is in a form suitable for subcutaneous injection. In this embodiment, the formulation is formed by mixing a powdered active agent with a liquid diluent that contains a pharmaceutically acceptable liquid carrier and one or more solubilizing agents. In the preferred embodiment, the active agent is insulin, and the diluent contains saline, EDTA and citric acid. Prior to administration the powder and diluent are mixed together to form an injectable composition.

Dry Powder

The composition may be in the form of a dry powder containing the pharmaceutically active agent and one or more excipient(s). Typically the dry powder composition is in a form suitable for oral, nasal or pulmonary administration. Typical routes for oral administration include buccal delivery and sublingual delivery. Preferably the composition is delivered sublingually. The active agent and excipient may be stored together or separately. The active agent and excipients may be stored together if the active agent is stable in the presence of the excipients. Alternatively, they may be stored separately, and then mixed before, during or after they are dispensed to the oral cavity. The powder rapidly dissolves upon mixing with saliva and effectively delivers the active agent to the systemic circulation via absorption through the sublingual epithelium.

The active agents and excipients may be in the form of particles having the same or different sizes. In one embodiment, the excipient particles are larger than the particles of agent. This will allow the small particles of agent to coat the larger particle so that both particles are administered simultaneously. Typically, the average particle diameter for the agent particles is less than or equal to one-tenth of the average particle diameter for the excipient particles. For sublingual delivery, the large particles generally have diameters greater than 8 μm , preferably greater than 20 μm . The average diameters for the large particles typically range from 8 μm to 500 μm , preferably from 50 μm to 150 μm . The small particles generally have a diameter ranging from 1 nm to 9 μm , preferably from 100 nm to 400 nm. For buccal and nasal administration, the particles generally have similar size ranges to those described from sublingual administration. For pulmonary administration, the large particles typically have an average diameter ranging from 1 μm to 10 μm , preferably from 2 μm to 5 μm ; and the small particles typically have an average diameter ranging from 10 nm to 1 μm .

If the particles of excipient have generally the same size, the average diameters will generally be greater than 8 μm , preferably greater than 20 μm , with typical size ranges from 8 μm to 500 μm , and preferably from 50 μm to 150 μm (for sublingual, buccal and nasal administration); and from 1 μm to 10 μm , preferably from 2 μm to 5 μm (for pulmonary administration).

Optionally, the particles are oppositely charged, so that the excipient particles contain one charge and the agent particles contain the opposite charge so that the particles are administered simultaneously. The particles may be charged by blowing them into a chamber formed of plastic surfaces, which impart charge to the particles. Two oppositely charged chambers may be used. The charged particles may be formed by using an acidic solution to make one of the particles, and a basic solution to form the other particles. Alternatively, charge can be transferred through ion discharge (e.g. using a staticizer or destaticizer). If the particles of agent and excipient are

oppositely charged, they may have the same average diameter or different average diameters.

In one embodiment, the components are stored separately, either in separate containers, a blister pack or capsules, which are combined at the
5 time of administration. In one embodiment, shown in Figure 2, the container is an ampoule 20 wherein the insulin is present in powdered form in the cap 22, separated from a solution 24 containing citric acid and EDTA. At the time of administration, the insulin is added to the solution 24 and administered. This may be accomplished by breaking a seal located at the
10 bottom 26 of the cap 22, for example, made of a polyethylene, which is ruptured by rotating the cap 22.

Film

The composition may be in the form of a film. The film is a clear or opaque, flexible, thin material. Typical thicknesses range from 0.01 to 2mm.
15 The film may have any suitable shape, including round, oval, rectangle, or square. The film may be a monolayer, bilayer or trilayer film. In the preferred embodiment, the film is designed to be suitable for sublingual administration. The monolayer film contains an active agent and one or more excipients. The bilayer film contains one or more excipients, such as a
20 solubilizing agent and/or a metal chelator, in a first layer, and an active agent in the second layer. This configuration allows the active agent to be stored separated from the excipients, and may increase the stability of the active agent, and optionally increases the shelf life of the composition compared to if the excipients and active agent were contained in a single layer. The
25 trilayer film contains three layers of film. Each of the layers may be different, or two of the layers, such as the bottom and top layers, may have substantially the same composition. In one embodiment, the bottom and top layers surround a core layer containing the active agent. The bottom and top layers may contain one or more excipients, such as a solubilizing agent and a
30 metal chelator. Preferably the bottom and top layers have the same composition. Alternatively, the bottom and top layers may contain different

excipient(s), or different amounts of the same excipient(s). The core layer typically contains the active agent, optionally with one or more excipients.

In the preferred embodiment, the film is a bilayer film that contains EDTA and citric acid in one layer and insulin in the second layer. Each layer
5 may contain additional excipients, such as glycerin, polyvinyl alcohol, carboxymethyl cellulose, and optionally PEG (such as PEG 400 or PEG 1600). In one embodiment, a third layer can be located between the active agent layer and the layer containing the other ingredients to further protect the active agent from degradative ingredients located in the other layer
10 during storage. Suitable materials for the protective layer include carboxymethylcellulose sodium, carnauba wax, cellulose acetate phthalate, cetyl alcohol, confectioner's sugar, ethylcellulose, gelatin, hydroxyethyl cellulose, hydroxypropyl methylcellulose, liquid glucose, maltodextrin, methylcellulose, microcrystalline wax, polymethacrylates, polyvinyl alcohol,
15 shellac, sucrose, talc, titanium dioxide, and zein.

By altering the composition of the excipients, the film can be designed to dissolve rapidly (less than 30 seconds) or slowly (up to 15 minutes) in order to achieve the desired absorption profile and subsequent effect. The film may dissolve in a time period ranging from 3 to 5 minutes, 5
20 to 8 minutes, or 8 to 12 minutes. Preferably, the film dissolves in a time period ranging from 15 seconds to 2 minutes.

Lozenge, Tablet, Capsule, or Wafer

In another embodiment, the composition is in the form of a lozenge, tablet, capsule, or wafer containing the active agent and one or more
25 excipients, such as chelators, stabilizing agents, solubilizing agents.

Lozenge

The lozenge core is composed of a solid gel or a lyophilized wafer, containing an active agent in the core. Optionally, the core also contains a stabilizing agent, optionally with one or more additional excipients.
30 Optionally, the upper and lower surfaces of the lozenge core are coated with a chelator, such as sodium EDTA. Alternatively, the chelator may be mixed with the active agent in the core. In the preferred embodiment, the core

contains alginate (preferably calcium stabilized alginate), citric acid, EDTA, and insulin. The lozenge covers a large surface area with a thin layer, and can be made in any convenient shape. Typically it has a round or oval shape. Generally, the lozenge has a diameter and thickness that is approximately the same as the diameter and thickness of a dime. In one embodiment, the lozenge contains glycerine.

Tablet

In one embodiment, the tablet is a compressed homogenous powder of all of the ingredients. In another embodiment, inactive ingredients, such as the filler and binding agent, and one or more excipients, including the solubilizing agents, are formed into one tablet. The active agent along with filler, binding agent, and other excipients are formed into another tablet. Then the two tablets are placed together and coated to form a single tablet. Optionally, the tablet is coated with an enteric coating.

Wafer

The composition may be in the form of a wafer. The wafer is a flat, solid dosage form. Typical thicknesses range from 0.1mm to 1.5cm. Typical diameters range from 0.2 to 5cm. The wafer may be in any suitable shape, including round, oval, rectangular, or square. The wafer may be a monolayer, bilayer or trilayer. In the preferred embodiment, the wafer is designed to be suitable for sublingual administration. The monolayer wafer contains an active agent and one or more excipients. The bilayer wafer contains one or more excipients, such as a solubilizing agent and/or a metal chelator, in a first layer and an active agent in the second layer. This configuration allows the active agent to be stored separated from the excipients, and may increase the stability of the active agent, and optionally increases the shelf life of the composition compared to if the excipients and active agent were contained in a single layer. The trilayer wafer contains three layers. Each of the layers may be different, or two of the layers, such as the bottom and top layers may have substantially the same composition. In one embodiment, the bottom and top layers surround a core layer containing the active agent. The bottom and top layers may contain one or

more excipients, such as a solubilizing agent and a metal chelator.

Preferably the bottom and top layers have the same composition.

Alternatively, the bottom and top layers may contain different excipient(s), or different amounts of the same excipient(s). The core layer typically

5 contains the active agent, optionally with one or more excipients.

Capsules

Another suitable dosage form is a capsule. The capsule contains a rapidly dissolving outer shell, which is typically composed of sugars, starches, polymers (and other suitable pharmaceutical materials). The capsule contains powders or granules of agent and excipient. The capsule is designed rapidly release powders or small rapidly dissolving granules into the oral cavity following administration.

Formulations for Subcutaneous Injection

The formulation may be an injectable formulation that is suitable for subcutaneous injection. The injectable formulation contains the active agent, a chelator, a solubilizing agent, and saline. In a preferred embodiment the injectable formulation contains insulin, EDTA, citric acid, and saline.

II. Methods of making the formulations

Pharmaceutical compositions may be formulated in a conventional manner using one or more physiologically acceptable carriers comprising excipients and auxiliaries which facilitate processing of the active compounds into preparations which can be used pharmaceutically. Formulation of drugs is discussed in, for example, Hoover, John E., Remington's Pharmaceutical Sciences, Mack Publishing Co., Easton, Pennsylvania (1975), and Liberman, H.A. and Lachman, L., Eds., Pharmaceutical Dosage Forms, Marcel Decker, New York, N.Y. (1980). Proper formulation is dependent upon the route of administration chosen.

The compounds may be complexed with other agents when they are formulated into the desired dosage form. If water-soluble, such formulated complex then may be formulated in an appropriate buffer, for example, phosphate buffered saline or other physiologically compatible solutions. Alternatively, if the resulting complex has poor solubility in aqueous

solvents, then it may be formulated with a non-ionic surfactant such as TWEEN™, or polyethylene glycol.

Preferred methods for making the films, tablets, wafers, and subcutaneous injectible formulations are described below.

5

Films

The monolayer film is typically formed by first suspending inactive ingredients and the active agent in water. The suspension is transferred, such as by pouring or pipetting, to a sheet or mold. Then the suspension is dried by lyophilization to remove the water and form a film. Films may be made as one large sheet and cut to a desired size, based on the desired dosage. Alternatively formulations containing a single dose may be manufactured by forming the film using a mold. The bilayer and trilayer films are generally formed in the same manner as the monolayer film with the exception that each layer contains only certain ingredients (e.g. one layer contains the active agent and the other layer contains one or more excipients).

10
15

Tablets

Tablets are made using a traditional compression machine with flat punches. Dry active ingredients are combined with an appropriate amount of an inert filler excipient such as a binding agent excipient, along with other suitable excipients. After mixing thoroughly, a predetermined amount of the mixture is placed into a tablet press and a tablet is formed. The depth of the tablet is determined by the quantity of ingredients. Compression should be sufficient to hold the ingredients together during dose administration, while allowing water penetration into the tablet for easy dissolution in the mouth.

20

25

Wafers

The wafer may be formed by compressing a powder, lyophilizing a cake, or evaporating a suspension, emulsion or gel (e.g. a hydrogel). A compression machine may also be used to make wafers using a larger, flatter punch. Alternatively, the mixed dry materials could be flattened or compressed between rollers to form the powder into a sheet that may be cut to an appropriate size that can be inserted in the mouth, preferably under the tongue. Dosing of the wafers can be determined by standard methods, such

30

as altering the concentration of the active agent in the powder and keeping the wafer size uniform. Alternatively, the concentration of the powder can be maintained, and the surface area of the wafer can be increased to achieve higher doses, or decreased to lower the dosage. In one embodiment, the
5 wafer is formed by suspending the active agent, solubilizing agents, binding agent or other excipients in a solvent such as water. A predetermined amount of the suspension is placed in wells in a plastic mold and lyophilized in the wells to remove the water and form a wafer. Alternatively, a bilayer wafer may be formed with the one or more excipients (e.g. solubilizing agent
10 and/or binding agent) in one layer and the active agent along with the binding agent or other inert components in the second layer.

Wafers can also be made by combining the dry powders into aqueous solution, pipetting the appropriate amount of solution into molds, flash freezing and lyophilizing the material. This forms a very light wafer that
15 dissolves very rapidly and requires little fill and binding material.

Formulations for Subcutaneous Injection

In the preferred embodiment, the subcutaneous injectable formulation is produced by mixing saline, citric acid and EDTA to form a solution and sterilizing the solution (referred to as the "diluent"). The insulin is separately
20 added to sterile water to form a solution, filtered, and a designated amount is placed into each of a number of separate sterile injection bottles. The insulin solution is lyophilized to form a powder and should be stored separately from the diluent to retain its stability. Prior to administration, the diluent is added to the insulin injection bottle. After the predetermined amount of
25 insulin is subcutaneously injected into the patient, the remaining insulin solution may be stored, preferably by refrigeration. The insulin solution should remain stable for at least one week.

III. Methods of Using Formulations

The formulations may be administered in a variety of manners,
30 including buccal administration, nasal administration, pulmonary administration, sublingual administration, subcutaneous administration, rectal administration, vaginal administration, or ocular administration.

Following administration, the dosage form dissolves quickly releasing the drug or forming small particles containing drug, optionally containing one or more excipients. The formulation is designed to be rapidly absorbed and transported to the plasma for systemic delivery.

- 5 Formulations containing insulin as the active agent may be administered to a type 1 or type 2 diabetic patient before or during a meal. The formulation is typically administered sublingually, or by subcutaneous injection. The formulation may also be administered by buccal, nasal or pulmonary administration. Due to the rapid absorption, the compositions can
- 10 shut off the conversion of glycogen to glucose in the liver, thereby preventing hyperglycemia, the main cause of complications from diabetes and the first symptom of type 2 diabetes. As seen in Example 2, the sublingual insulin formulations deliver insulin to the blood stream of the patient quickly, resulting in a rapid onset of action (beginning at about 5
- 15 minutes following administration and peaking at about 15-30 minutes following administration). In contrast, currently available, standard, subcutaneous injections of human insulin must be administered about one hour prior to eating to provide a less than desired effect, because the insulin is absorbed too slowly to shut off the production of glucose in the liver.
- 20 Additionally, if given early enough in the progression of the disease, the sublingual or subcutaneous insulin compositions may be able to slow or stop the progression of type 2 diabetes.

- Figure 1A is a schematic for administering the preferred dry powder composition, i.e. insulin, alginate, citric acid, and EDTA powder. As shown
- 25 in Figure 1A, the powder is composed of a solid, dry powder of citric acid, insulin, and EDTA powder. A device is used to dispense a single dose of dry powder under the tongue, so that the dose is evenly dispersed throughout the sublingual region of the oral cavity. The disodium EDTA rapidly dissolves in the saliva. The citric acid solubilizes the insulin, allowing it to be in
- 30 solution in close proximity with the EDTA. The EDTA then chelates the zinc in the insulin, thereby releasing its sodium ions and pulling the zinc away from the insulin. This causes the insulin to take on its dimeric and

monomeric form and prevents reassembly into hexamers. The monomeric form has a molecular weight that is less than one-sixth the molecular weight of the hexameric form, thereby markedly increasing both the speed and quantity of insulin absorption. The dimers and monomers are in equilibrium.

- 5 Thus, as insulin monomers are absorbed through the epithelial membrane, additional dimers dissemble to form more monomers.

A similar process occurs if a bulking agent is included in the drug powder. For example, if alginate is used as a bulking agent for the insulin, the calcium embedded in the alginate is chelated by the EDTA, removing it
10 from the gel matrix. This de-stabilizes the matrix, which releases the insulin into the local saliva, where insulin is now in close proximity to the EDTA. The EDTA identifies the zinc-insulin in close proximity, and exchanges its calcium for the zinc, for which it has a higher affinity. This releases the hexameric insulin into its dimeric form, of which a portion splits into
15 monomers. Since these two forms exist in a concentration-driven equilibrium, as the monomers are absorbed, more monomers are created. These small polypeptides of ~5,800 Da are now ready for epithelial absorption. Since the epithelium is relatively thin in the sublingual region, and blood vessels are readily available, the systemic absorption is fast and
20 efficient. To the extent that the EDTA and/or citric acid hydrogen bond with the insulin, it masks the charge on the insulin, facilitating its transmembrane transport and thereby increases both the onset of action and bioavailability for insulin. Since the epithelium is relatively thin in the sublingual region, and blood vessels are readily available, the systemic absorption is fast and
25 efficient, taking from 1 second to 15 minutes following administration. The powder may dissolve in a time period ranging from 1 second to 3 minutes, 3 to 5 minutes, 5 to 8 minutes, or 8 to 12 minutes. The preferred dissolution time is less than 5 minutes.

As described in Figure 1B, before a meal, a lozenge is inserted under
30 the tongue, and tongue is relaxed on top of the lozenge 10. The lozenge could be replaced with a film, wafer, tablet, or capsule. The sodium EDTA is dissolved from the surfaces 12 and into the local saliva. The surface 12 of

the lozenge is wetted by the removal of the EDTA layer, providing the embedded calcium in the gel 10 with access to the surface 12. EDTA is a calcium chelator, and removes the calcium from the gel matrix, removing its supporting structure. With the calcium removed, the alginate liquefies, and releases the hexameric zinc insulin into the saliva. The EDTA is attracted to the zinc in close proximity, and removes the zinc from the insulin (for which it has a higher affinity), releasing the hexameric insulin into its dimeric form, of which a portion splits into monomers. Since the monomers and dimers exist in a concentration-driven equilibrium, as the monomers are absorbed, more monomers are created.

IV. Kits

The active agent can be stored in one container and the excipients can be stored in a second container. Immediately prior to administration the contents of both containers are mixed.

As illustrated in Figure 2, the kit may contain a vial containing powdered insulin in the cap (22), separated by a seal (26) which can be broken by rotation of the cap, to allow the insulin to mix with the excipient, e.g. citric acid-EDTA, solution in the vial (24).

The methods and compositions described above will be further understood with reference to the following non-limiting examples.

Examples

Example 1: Effect of Insulin Solutions Containing Different Concentrations of EDTA on Conversion of Insulin from a Hexameric Form to Monomer/Dimers.

Materials

Human recombinant Insulin (Akzo-Nobel), Citric acid and disodium EDTA were used in this experiment in distilled water. Nanosep microtubes with 30,000 MW cutoff (Pall Scientific) were used to separate the hexamers (36,000 MW) from the dimers/monomers (6-12,000 MW) in the insulin solutions. Analysis was performed by HPLC using a waters 2695 separations module fitted with a symmetry 300™ C₄ 5um column (Waters Corp, Milford, MA, #186000285) and a photodiode array detector (at 220nm

absorbance). A gradient method (25-32% ACN in water, 0.05%TFA) was used to separate the insulin from the other ingredients.

Methods

- Human recombinant Insulin was dissolved in 2mg/mL Citric acid to form a 1 mg/ml solution and 1.5mL of this solution was subsequently pipetted into test tubes. EDTA was added to each tube in order to achieve a concentration of 0, 1, 2, 3, or 4 mg EDTA/mL. 0.5 mL of the combined ingredients were added to the top of the Nanosep microtubes and tubes were spun at 10,000 rpm for 10 minutes in a microcentrifuge (Fisher Scientific). Insulin was assayed before and after the spin, and the percent recovered in the filtrate was determined by dividing the amount of the insulin that filtered through the filter by the initial quantity placed on top.

Setup

Table 1: Four experimental conditions and control

Formulation No.	Insulin (mg/ml)	EDTA (mg/mL)	Citric acid (mg/mL)
0	1	0	2
1	1	1	2
2	1	2	2
3	1	3	2
4	1	4	2

Results

As shown in Figure 3, increasing amounts of EDTA resulted in greater concentrations monomers/dimers relative to hexamer in the insulin solution. About 8% of the total insulin was filtered through the filter when
5 no EDTA was present (control "0"). The quantity of monomer/dimers recovered in the filtrate increased to over 20% after the addition of EDTA, with a maximal effect at 2 mg/mL. Further addition of EDTA did not enhance the effect. Thus, the addition of EDTA to an insulin solution (in the presence of citric acid) increases the concentration of monomers/dimers.

10 Example 2: Effect of Administration of Sublingual Dry Powder Insulin Formulation on a Patient's insulin and glucose levels.

The insulin and blood glucose levels following a single sublingual administration of a dry powder insulin formulation were measured in one male, 35-year old, Type 1 diabetic patient. The dose administered to the
15 patient contained 6 mg insulin, 4 mg citric acid and 4 mg EDTA. The insulin in the formulation was approximately 28 IU/mg.

The patient fasted overnight and arrived at the clinic in the early morning. An IV line with a saline drip was attached to the patient. The patient was instructed to open his mouth and touch his upper palette with his
20 tongue and the dry powder formulation was sprinkled under his tongue. He was then instructed to lower his tongue, close his mouth and not swallow for one minute.

Blood glucose was measured at five minutes prior to the application of the sublingual insulin formulation. Following administration of the
25 insulin formulation, blood glucose was monitored in real time by the use of glucose strips and samples of blood were taken according to the times listed in Tables 2 and 3 for a laboratory determination of blood glucose concentration by the glucose oxidase method and of blood insulin concentration by a LINKO enzyme linked immunosorbent assay (ELISA).

30 Results and Discussion

Data obtained using the glucose strip method and glucose oxidase method are listed in Table 2.

Table 2: Glucose Concentrations over Time

Time (minutes)	Strip Method Glucose concentration (mg/DL)	Oxidase Method Glucose concentration (mg/DL)
-5	N/A	99.5
3	84	96.3
7	83	87.0
10	75	90.1
15	70	83.2
20	73	78.3
30	63	75.5
45	59	68.0
60	46	61.8
61	42	60.2
62	42	57.7
80 (glucose ingestion)	33	53.7
90	136	143
120	97	122.0
145	N/A	122.0
180	N/A	80.5

By the real-time glucose strip method, the blood glucose concentration dropped rapidly and precipitously, starting within 10-15 minutes after administration. By one hour post administration, blood glucose appeared to be dangerously low (46 mg/DL by the strip method). The initial protocol was modified at this time, and the blood glucose readings were taken more frequently. At 80 minutes post administration, the patient's blood glucose was 33mg/DL by the strip method, and a liquid formulation of glucose was orally administered to the patient. This intervening administration of glucose was effective at raising the patient's blood glucose levels to the normal range (95-140 mg/DL) by the strip method. In contrast

to this oral dosage, a subcutaneous injection of human insulin typically begins to lower blood glucose about 30 minutes after administration and produces a peak effect between 90 minutes and 3 hours after administration.

As seen based on the data in Table 2, the data obtained using the more accurate test for blood glucose, the oxidase method, mirrored the real time strip method, but was higher by about 12-20 mg/DL on an absolute basis.

Table 3 lists the blood insulin concentrations over time obtained by the LINKO ELISA test.

10

Table 3: Insulin concentrations over time

Time (minutes)	Insulin concentration (μU/mL)
-5	16.9
3	13.9
7	22.7
10	21
15	22.95
20	23.4
30	19.7
45	21.2
60	21.9
80	21.1
(glucose ingestion)	
120	18.9
180	13.9

As seen in based on the data listed in Table 3, the blood insulin concentration rose very rapidly, beginning at 7 minutes after administration and reached a peak effect between 15 and 20 minutes after administration.

15 In contrast, a subcutaneous injection of human insulin achieves maximum blood concentration about two hours after administration. Thus the dry

powder sublingual formulation is about 6 to 8 times faster than a subcutaneous injection of human insulin.

Example 3: Determination of Effect of EDTA and Various Acids on Insulin Particle Size.

5 A study was conducted to determine the effect of EDTA, a chelator, in combination with various acids: acetic acid, hydrochloric acid, ascorbic acid and citric acid, on insulin particle size. Controls included insulin with EDTA and no acid, and insulin with acid and no EDTA.

10 Using the same techniques described in example 1, insulin (1 mg/ml) was dissolved in a food acid, EDTA added, and the mixture on top of a 30,000 mw cutoff filter in a microtube, and then spun for 10 minutes at 10,000 rpm. Each mixture was tested at pH 3 (without buffer) and pH 7.0 (with phosphate buffer). The results were calculated as a percent of insulin recovered in the filtrate, compared to the starting quantity (percent).

15 The results are depicted graphically in Figures 4 and 5a-d. The results show that the combination of EDTA and citric acid produces a significantly greater amount of lower weight (i.e., monomeric rather than hexameric) insulin.

Example 4: Subcutaneous Administration of EDTA Insulin to Pigs

20 The EDTA-citric acid insulin formulation was administered by subcutaneous injection to pigs to compare the effect of EDTA and citric acid on insulin administered by subcutaneous administration with normal (hexameric) human insulin. The insulin was administered in a dosage of 25 U/ml, 2 mg EDTA/ml, 2 mg citric acid/ml. An insulin dose of 0.125 U/kg was administered. The effect on blood glucose was compared to the effect of 25 100 units regular human insulin, dose 0.125 U/kg.

30 Normal human insulin normally produces its lowest glucose level at about 120 minutes after administration, with levels returning to baseline over a period of six hours. In contrast, as shown by the results in Figure 6, the EDTA-citric acid insulin formulation produces a more rapid and significantly greater decrease in blood glucose.

Example 5: Determination of Effect of EDTA on Insulin Absorption Through a Membrane Overlayed with an Epithelial Cell Monolayer

A study was conducted to demonstrate the effect of EDTA on absorption through a membrane overlayed with an epithelial cell monolayer.

5 Two saline solutions were mixed containing 1mg/ml insulin, 2 mg/ml EDTA and 2 mg/ml citric acid ("solution 1") or 1mg/ml insulin and 2mg/ml citric acid ("solution 2"). The control solution contained only EDTA and citric acid. Immortalized epithelial cell line cultures were seeded on transwell membranes. When the cells were grown to confluence, at time
10 zero, the fluid in the top chambers of the transwell plates was replaced with 0.5 ml of insulin solution (i.e. solution 1 or solution 2). Two plates with solution 1, two plates with solution 2 and one plate with the control solution (no cells) were tested simultaneously. The lower chamber of each plate contained 1.5mL of saline solution. At each time point, 100μL of fluid from
15 the lower chamber was removed and analyzed with Enzyme-Linked Immunosorbent Assay (ELISA). 100μL of saline was added to the lower chamber to maintain a constant volume of 1.5 mL throughout the study.

The amount of insulin removed from the lower chamber at each time point was added to the amount removed in the previous time point(s) to
20 determine the cumulative amount of insulin recovered in the lower chamber. This data is presented in Figure 7.

Cells were stained to check for viability before and after the experiment. There was no statistical difference in the cell viability for each of the plates.

25 The mean insulin accumulated in the lower chamber (receiver chamber) over time is shown in Figure 7. As shown in Figure 7, solution 1, which contained EDTA, moved through the monolayer of epithelial cells and through the membrane more effectively than solution 2, which did not contain EDTA.

30

We claim:

1. A composition comprising a biologically active agent, a solubilizing agent and a metal chelator, in a form suitable for sublingual or subcutaneous administration.
2. The composition of claim 1, wherein the agent is selected from the group consisting of insulin and derivatives thereof; C-peptide; glucagon-like peptide 1 (GLP 1) and active fragments thereof; human amylin and synthetic forms thereof; parathyroid hormone (PTH) and active fragments thereof (e.g. PTH₁₋₃₄); calcitonin; human growth hormone (HGH); erythropoietin (EPO); macrophage-colony stimulating factor (M-CSF); granulocyte-macrophage-colony stimulating factor (GM-CSF); and interleukins.
3. The composition of claim 2, wherein the agent is insulin or a derivative thereof.
4. The composition of claim 1, wherein the chelator is selected from the group consisting of ethylenediaminetetraacetic acid (EDTA), dimercaprol (BAL), penicillamine, alginic acid, Chlorella, Cilantro, Alpha Lipoic Acid, Dimercaptosuccinic Acid (DMSA), dimercaptopropane sulfonate (DMPS), and oxalic acid.
5. The composition of claim 4, wherein the chelator is ethylenediaminetetraacetic acid (EDTA).
6. The composition of claim 1, wherein the agent is a charged compound and wherein the chelator and solubilizing agent are present in effective amounts to mask charges on the agent.
7. The composition of claim 1 wherein the solubilizing agent is an acid selected from the group consisting of acetic acid, ascorbic acid, citric acid, and hydrochloric acid.
8. The composition of claim 1 in a form selected from the group consisting of dry powders, tablets, wafers, films, lozenges, and capsules.
9. The composition of claim 8, wherein the composition is in the form of a trilayer film or wafer suitable for sublingual delivery.
10. The composition of claim 1 in a form suitable for sublingual delivery.

11. A kit comprising a first storage container and a second storage container, wherein the first storage container comprises a pharmaceutically active agent and wherein the second storage container comprises a solubilizing agent and a metal chelator.

12. The kit of claim 11 wherein the first container is a cap and the second container is a vial the cap is secured to, and wherein the two containers are separated by a barrier.

13. A method of delivering a biologically active agent to a patient comprising administering sublingually or via subcutaneous injection a composition comprising an effective amount of the agent, a solubilizing agent and a metal chelator.

14. The method of claim 13, wherein the agent is selected from the group consisting of insulin and derivatives thereof; C-peptide; glucagon-like peptide 1 (GLP 1) and active fragments thereof; human amylin and synthetic forms thereof; parathyroid hormone (PTH) and active fragments thereof (e.g. PTH₁₋₃₄); calcitonin; human growth hormone (HGH); erythropoietin (EPO); macrophage-colony stimulating factor (M-CSF); granulocyte-macrophage-colony stimulating factor (GM-CSF); and interleukins.

15. The method of claim 14; wherein the agent is insulin or a derivative thereof.

16. The method of claim 13, wherein the chelator is selected from the group consisting of ethylenediaminetetraacetic acid (EDTA), dimercaprol (BAL), penicillamine, alginic acid, Chlorella, Cilantro, Alpha Lipoic Acid, Dimercaptosuccinic Acid (DMSA), dimercaptopropane sulfonate (DMPS), and oxalic acid.

17. The method of claim 16, wherein the chelator is ethylenediaminetetraacetic acid (EDTA).

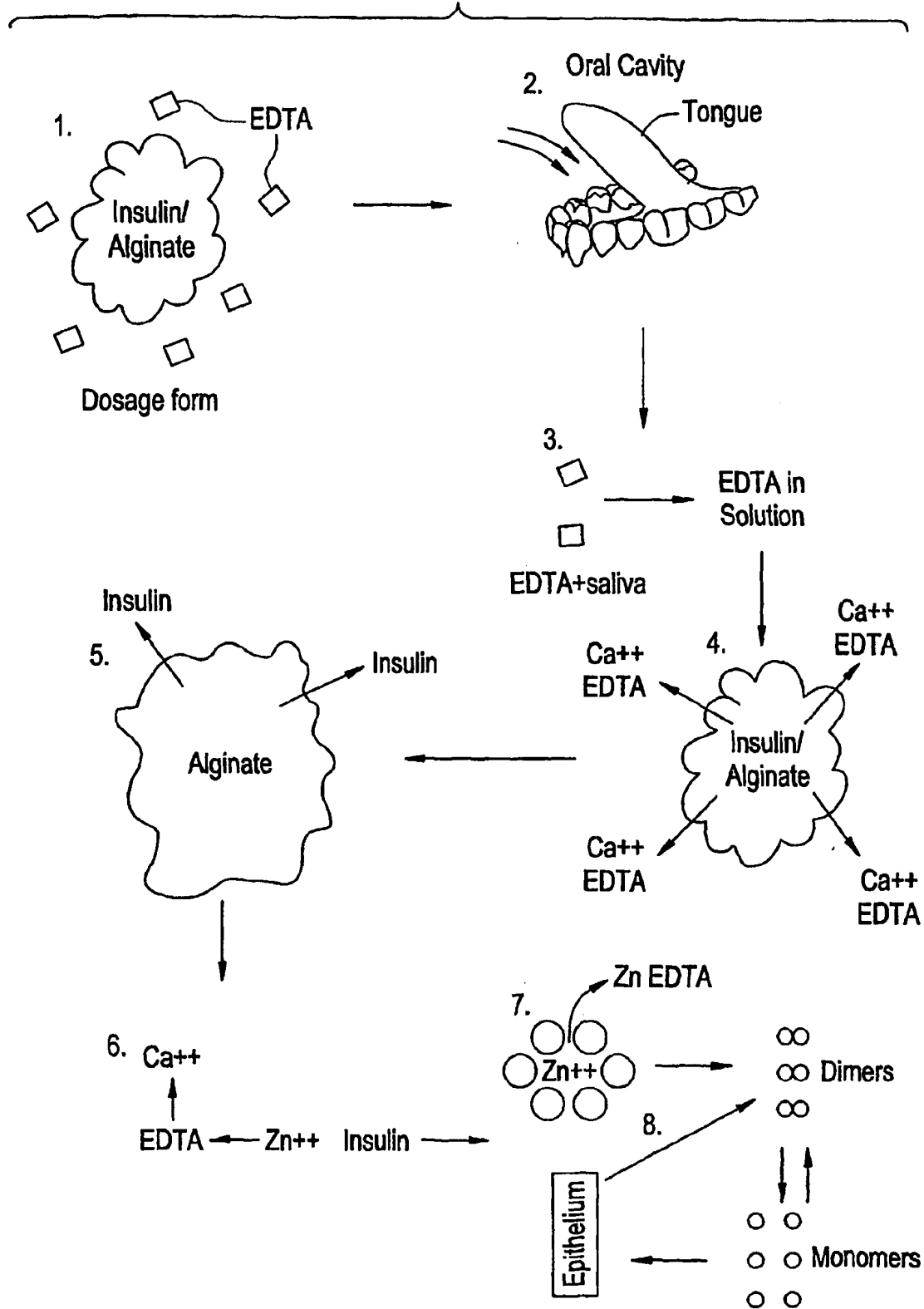
18. The method of claim 13, wherein the agent is a charged compound and wherein the chelator and solubilizing agent are present in effective amounts to mask charges on the agent.

19. The method of claim 13, wherein the solubilizing agent is an acid selected from the group consisting of acetic acid, ascorbic acid, citric acid, and hydrochloric acid.

20. The method of claim 13, wherein the composition is in a form selected from the group consisting of dry powders, tablets, wafers, films, lozenges, and capsules.

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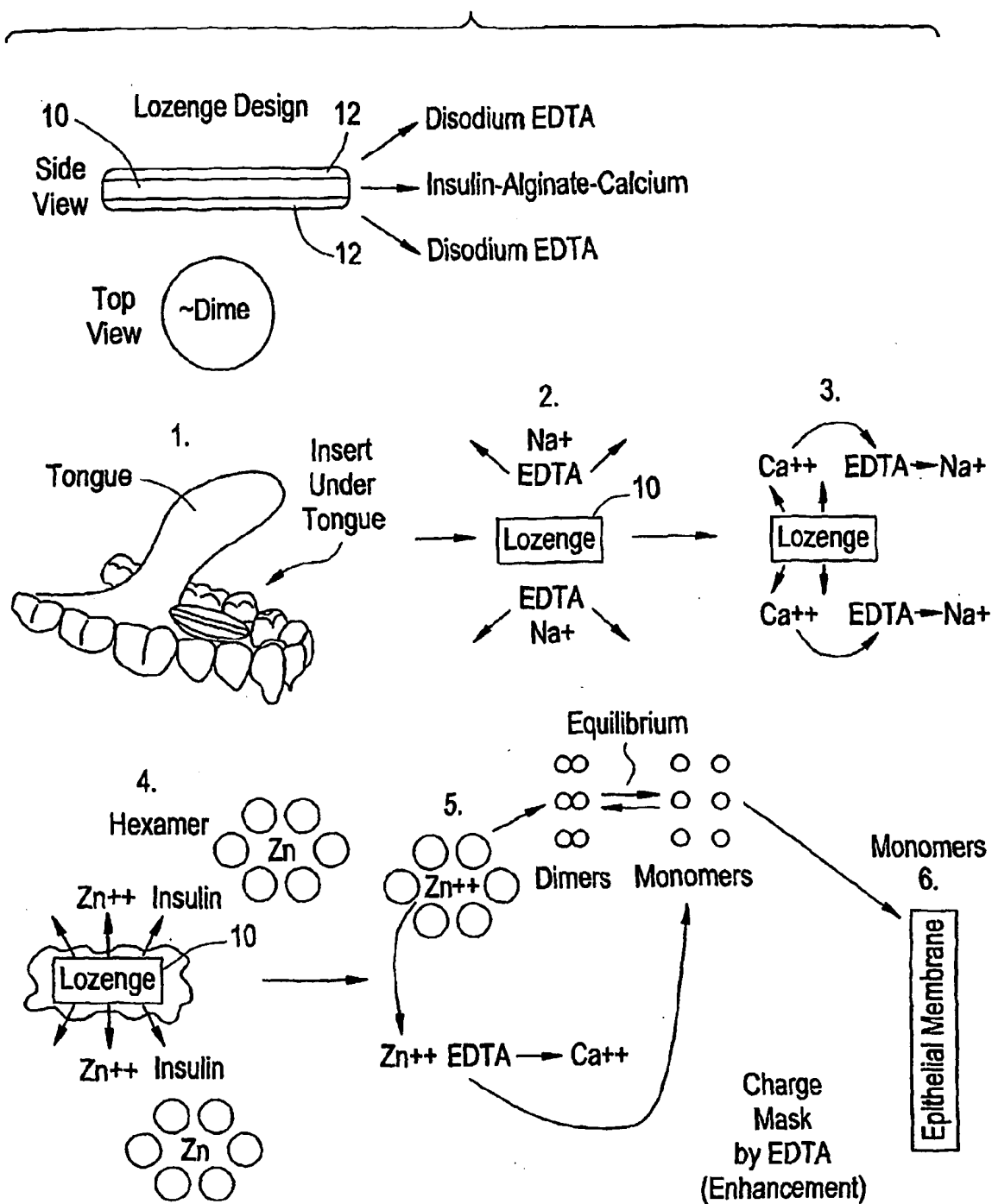
FIG. 1A



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FIG. 1B



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FIG. 2

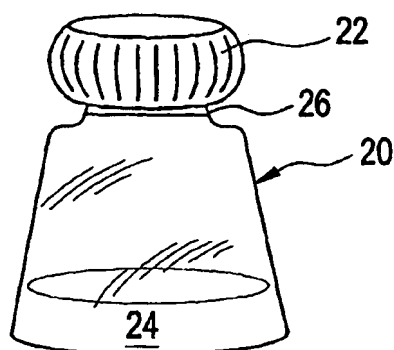
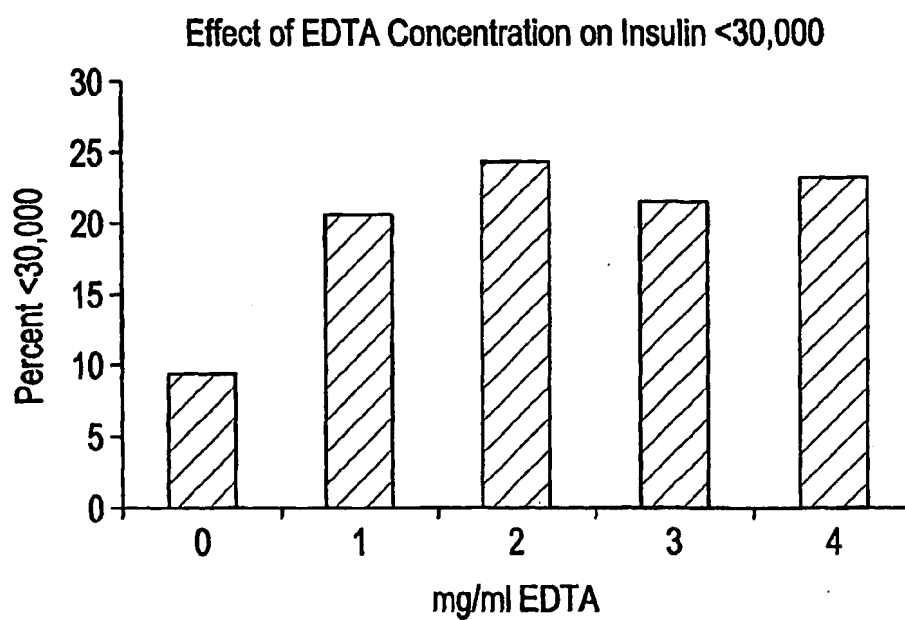


FIG. 3



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FIG. 4

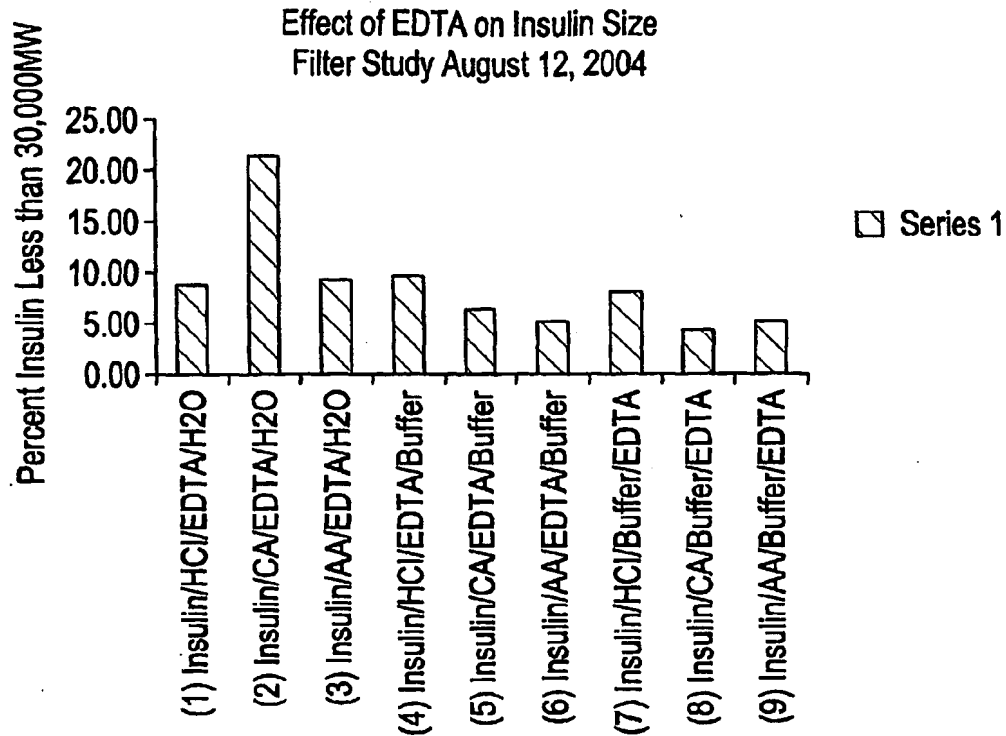
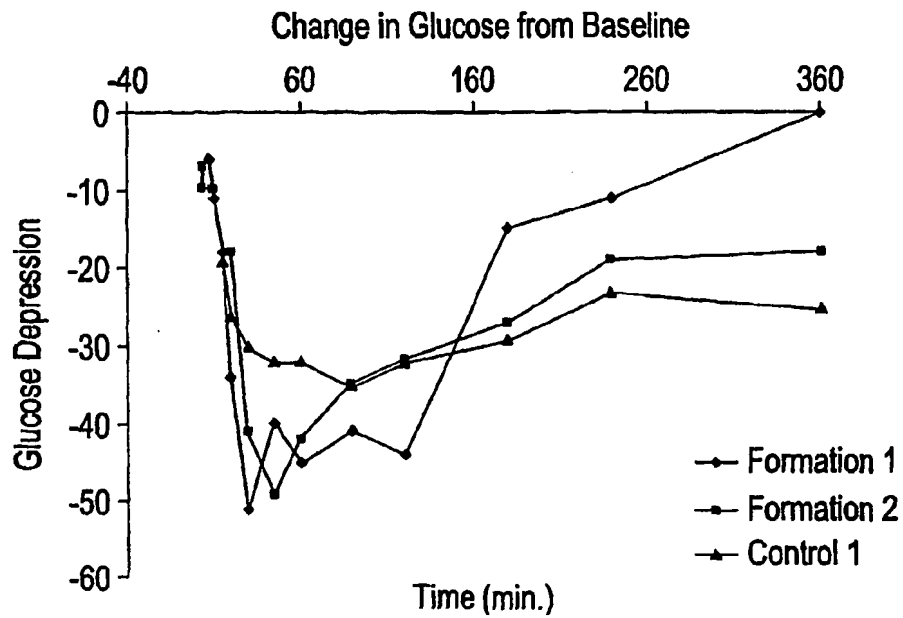


FIG. 6



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FIG. 5A

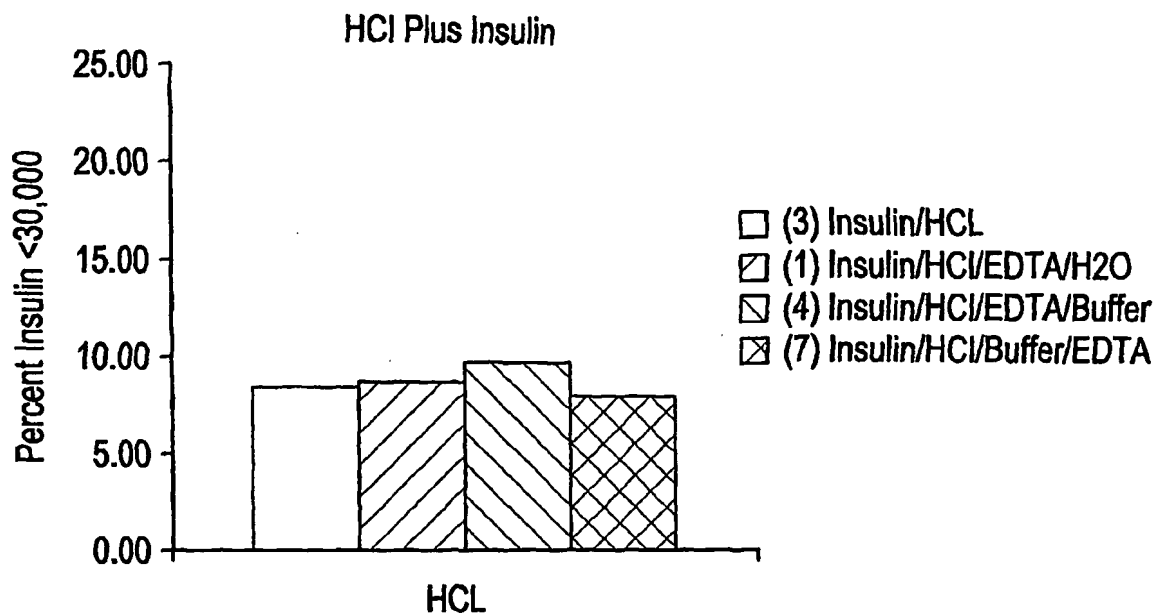
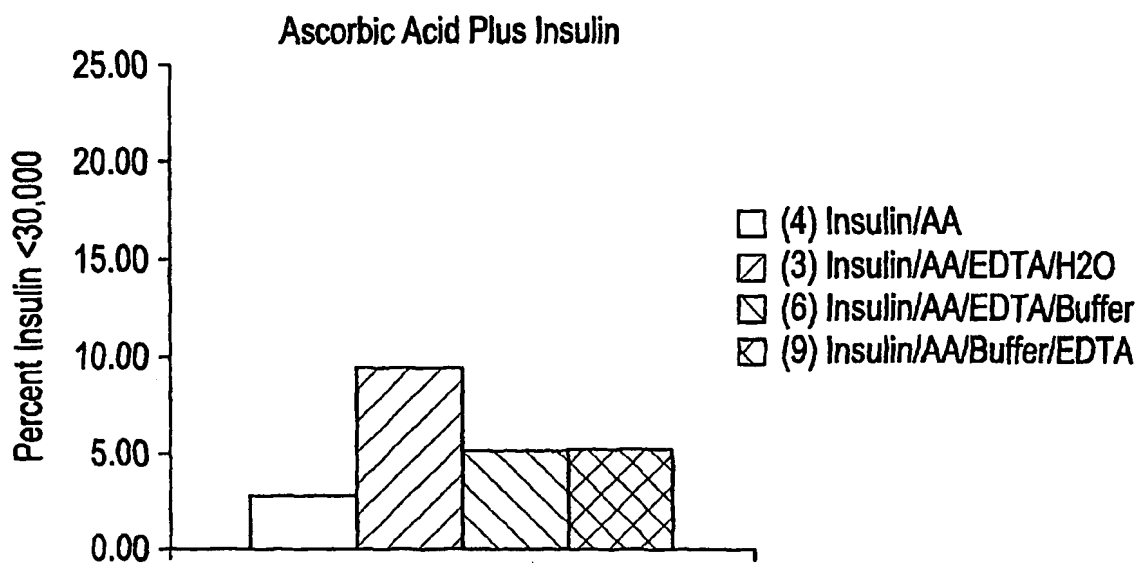


FIG. 5B



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FIG. 5C

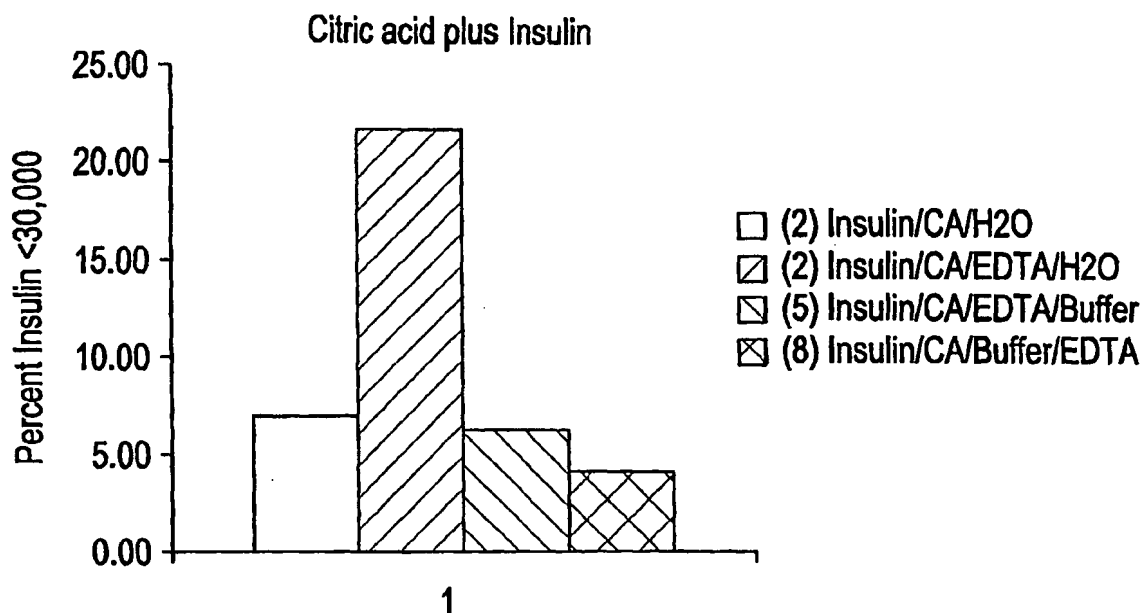
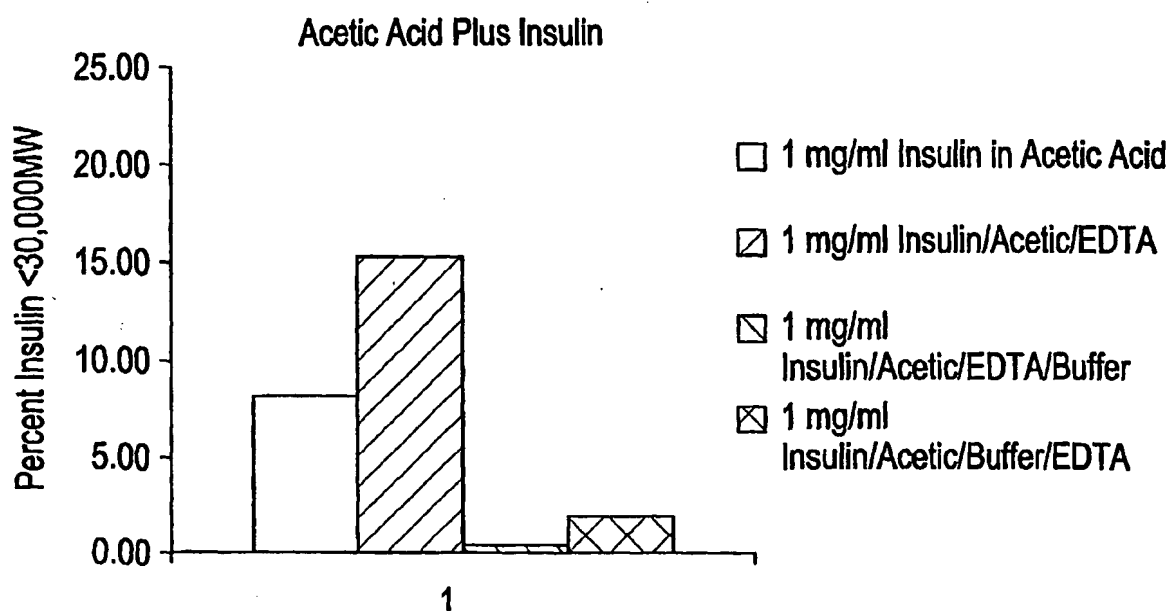


FIG. 5D

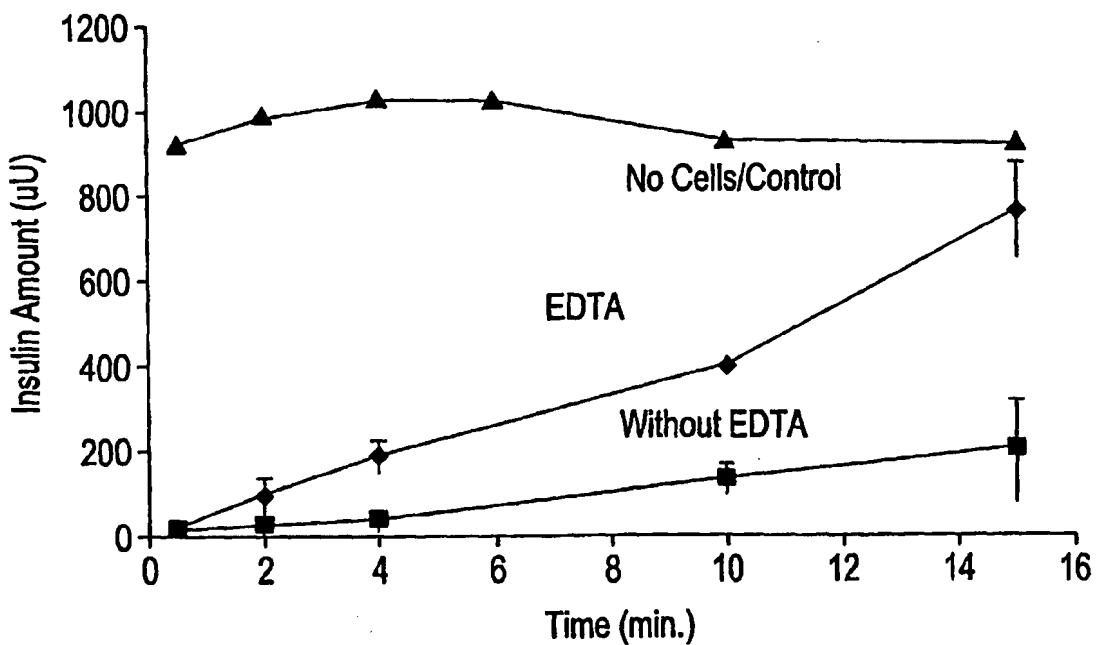


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FIG. 7

Mean Insulin Accumulated in Transwell
Receiver Chamber



INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/008187

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61K9/20 A61K38/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, BIOSIS, MEDLINE, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 2004/056314 A (NASTECH PHARMACEUTICAL COMPANY INC; QUAY, STEVEN, C; BRANDT, GORDON; K) 8 July 2004 (2004-07-08) page 8, lines 5-7, 17-20 page 3, lines 33-36 page 11, lines 19-23, 28 page 33, lines 20-34 examples 4, 5 claims	1-6, 8, 10, 13-18, 20
X	US 5 929 027 A (TAKAMA ET AL) 27 July 1999 (1999-07-27) example 6 claims	1-3, 6-8, 13-15, 17-19
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *Z* document member of the same patent family

Date of the actual completion of the international search

21 June 2005

Date of mailing of the international search report

06/07/2005

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Authorized officer

Villa Riva, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/008187

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/068378 A1 (CHEN LI-LAN H ET AL) 10 April 2003 (2003-04-10) paragraphs '0011!, '0016!, '0028! paragraphs '0044!, '0046!, '0047! tables 5,7 -----	1,4-6, 9-13, 17-20
X	US 6 432 383 B1 (MODI PANKAJ) 13 August 2002 (2002-08-13) abstract column 1, lines 42-60 column 3, lines 41-45 column 5, lines 1-14 column 6, lines 19-34 claims -----	1-6,10, 13-18,20
X	US 6 395 744 B1 (ADAMS MICHAEL A ET AL) 28 May 2002 (2002-05-28) table 1 -----	1,6-8, 10,13, 18-20
A	WO 97/49386 A (PEPTIDE DELIVERY SYSTEMS PTY. LTD; REDGRAVE, TREVOR, GORDON; MARTINS,) 31 December 1997 (1997-12-31) the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2005/008187

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claims 13-20 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

 International Application No
 PCT/US2005/008187

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2004056314	A	08-07-2004	US 2004115135 A1	17-06-2004
			AU 2003299722 A1	14-07-2004
			WO 2004056314 A2	08-07-2004
			US 2004157777 A1	12-08-2004
			US 2004209807 A1	21-10-2004
			US 2004214772 A1	28-10-2004
			US 2005002927 A1	06-01-2005
US 5929027	A	27-07-1999	AT 276767 T	15-10-2004
			AU 653026 B2	15-09-1994
			AU 1726492 A	10-12-1992
			CA 2070061 A1	08-12-1992
			DE 69233413 D1	28-10-2004
			EP 0517211 A1	09-12-1992
			ES 2229203 T3	16-04-2005
			FI 922579 A	08-12-1992
			JP 3253127 B2	04-02-2002
			JP 5148154 A	15-06-1993
			NO 922232 A	08-12-1992
			SG 43858 A1	14-11-1997
US 2003068378	A1	10-04-2003	US 6552024 B1	22-04-2003
			AU 7354501 A	30-01-2002
			CA 2417736 A1	24-01-2002
			EP 1301186 A1	16-04-2003
			WO 0205820 A1	24-01-2002
			AU 776525 B2	16-09-2004
			AU 2222600 A	07-08-2000
			BR 9917089 A	16-10-2001
			CA 2358524 A1	27-07-2000
			CN 1354656 A	19-06-2002
			CZ 20012566 A3	16-01-2002
			EP 1143940 A2	17-10-2001
			HU 0203168 A2	28-01-2003
			JP 2002535269 T	22-10-2002
			MX PA01007411 A	06-06-2003
			NO 20013536 A	20-09-2001
			NZ 512984 A	31-10-2003
			PL 353354 A1	17-11-2003
			WO 0042992 A2	27-07-2000
			ZA 200105968 A	21-10-2002
US 6432383	B1	13-08-2002	NONE	
US 6395744	B1	28-05-2002	US 5770606 A	23-06-1998
			US 2002193442 A1	19-12-2002
			AU 4254799 A	10-01-2000
			CA 2334550 A1	29-12-1999
			WO 9966909 A2	29-12-1999
			EP 1089736 A2	11-04-2001
			JP 2002518435 T	25-06-2002
			MX PA01000275 A	24-04-2002
			US 2002165122 A1	07-11-2002
			US 2003073715 A1	17-04-2003
			US 5985889 A	16-11-1999
			US 6121276 A	19-09-2000
			US 6200983 B1	13-03-2001
			US 2004092493 A1	13-05-2004

INTERNATIONAL SEARCH REPORT

 International Application No
 PCT/US2005/008187

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6395744	B1	US 6306437 B1	23-10-2001
		AT 189121 T	15-02-2000
		AU 703608 B2	25-03-1999
		AU 2295895 A	16-11-1995
		CA 2188385 A1	02-11-1995
		DE 10199068 I1	05-06-2003
		DE 69514794 D1	02-03-2000
		DE 69514794 T2	27-07-2000
		DK 758895 T3	13-06-2000
		EP 0758895 A1	26-02-1997
		EP 0978282 A2	09-02-2000
		ES 2143049 T3	01-05-2000
		GR 3033084 T3	31-08-2000
		HK 1014239 A1	09-02-2001
		JP 3310982 B2	05-08-2002
		JP 9512273 T	09-12-1997
		LU 90856 A9	24-01-2002
		NL 300072 I1	01-02-2002
		PT 758895 T	31-05-2000
		WO 9528930 A1	02-11-1995
<hr/>			
WO 9749386	A	31-12-1997	AU 2944197 A
			14-01-1998
			WO 9749386 A1
			31-12-1997
<hr/>			